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ABSTRACT

The Wisconsin model of conceptual learning and development specifies four levels of mastery in the acquisition of a concept. The levels of mastery are defined in terms of performance on tasks designed to measure each level. This paper discusses the internal operations or processes which are inferred as the mechanisms by which each level of performance is attained under specific stimulus conditions. The operations at each level, together with the attainment of the concept at preceding levels, constitute the internal conditions of concept learning. (SBT)

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The Cognitive Operations Specified in the Model[1, 2]

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The Cognitive Operations Specified in the Model

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The Wisconsin model of conceptual learning and development (CLD model), which has been outlined, specifies four levels of mastery in the acquisition of a concept. The levels of mastery are objectively defined in terms of performance on tasks designed to measure each level. The description of these tasks will be presented in a later paper. What I will be concerned with are the internal operations or processes which are inferred as the mechanisms by which each level of performance is attained under specified stimulus conditions. The operations at each level together with the attainment of the concept at preceding levels constitute the internal conditions of concept learning.

The operations specified in the CLD model are quite familiar to American students of concept learning since they have largely been derived from the American literature in such areas as attention, discrimination, memory, and so on. The purpose of the logical analysis of operations contained in the CLD model is to provide a descriptive framework which can serve as a basis for organizing the existing knowledge in the field of concept learning and provide guidelines for research on the external and internal conditions of concept learning in school settings.

Let me now describe the operations postulated to be involved in the attainment of the successive levels of concept mastery and briefly cite some of the research pertaining to the operations at each level.

Concrete Level

The learner has attained a concept at the concrete level when he can correctly identify a stimulus as one he has encountered before. Figure 1 shows the operations postulated to occur in attaining the concrete level. These operations are involved in learning to recognize stimuli, whether the stimuli are objects, figural representations of objects, or symbols.

The initial operation is attending to the stimulus in the sense of orienting one's receptors--an obvious prerequisite for any type of learning. The second operation of discriminating the stimulus from other stimuli involves attending to those properties or combination of properties of the object which differentiate it from other stimuli. The properties of the stimulus, which are attended to, depend upon factors internal to the learner, such as past experience with other stimuli and characteristics of the stimulus situation, such as the number and degree of similarity among stimuli to be discriminated. Gibson (1969) has pointed out that complex objects in real life can seldom be differentiated on the basis of single properties which render them unique. Rather, they are identifiable on the basis of a bundle of properties which must be discovered by the perceiver.

The final operation at the concrete level is remembering the discriminated stimulus. It is suggested that, as a result of the learner's attending to and discriminating an object from other objects, a memory image is formed which is a schematic representation of the object. This view is similar to that of Hebb (1968) and Gibson (1969) in presuming that a representational image results from active exploration of the features of an object.

Formation of a memory image of the stimulus is the final operation at the concrete level. However, another operation which may occur is verbal labeling of the stimulus. Since adequate stimulus recognition can occur in the absence of labels (Paivio, 1971), this operation is not a necessary one for attaining the concrete level.

Identity Level

The next level of concept mastery, the identity level, is attained when the learner recognizes that an object is the same one previously encountered despite changes in sensory modality, perspective, context, and other transformations. The formation of a concrete-level concept of the object or the ability to do so is assumed to be a necessary precursor to attaining the identity level. Thus, Figure 2 shows that the operations leading to the memorial representation of a discriminated stimulus are included at the identity level. One new operation is entailed at this level and that is generalizing that two or more forms of the same thing are equivalent.

The ability to recognize an object as the same object despite changes in its apparent size, orientation, context and so forth is well developed in adults. Therefore, what evidence there is concerning formation of concepts at the identity level comes from research on perceptual-cognitive development in infancy. Early in the infant's development he realizes that the same object can be a source of more than one type of sensory pattern. That is, he learns that the same object can be sensed in more than one modality and he learns to coordinate these sensory patterns in recognizing an object. It appears that generalization across the auditory and visual modalities develops by two or three months of age. Generalizing that an object that he sees is the same that he touches and mouths occurs somewhere around four to five months of age (Vernon, 1970).

Bower (1966b) found that infants of two months, who were trained to respond to an object at a given distance, generalized that response to the same-sized object at different distances. Thus, infants recognize an object's "real" size very early.

Generalization across changes in an object's orientation in the visual field also develops quite early. Bower (1966a) found that infants of two months could still recognize an object when its orientation was slightly changed. Research by Hunton (1955) and Ghent (1960) shows that generalization across more drastic changes in orientation continues to develop through childhood, especially with respect to recognition of objects from pictures.

As noted for the concrete level, labeling of the concept may be an operation at the identity level but is not a necessary operation at this level.

Classificatory Level

The learner has attained a concept at the classificatory level when he can correctly group together things which are in some way equivalent, although he may be unable to describe the basis for his grouping. This level of concept attainment generally corresponds to the definition of a concept in experimental psychology (Bourne, 1966). The operations involved in attaining this level are shown in Figure 3.

Attainment of a concept at the classificatory level depends upon prior attainment of the identity level since an individual must be able to consistently recognize a thing before he can consistently group that thing with other things on the basis of properties which they have in common. The additional operation at the classificatory level is generalizing among discriminable instances on the basis of commonalities. Most experimental studies of concept

learning use measures which assess only this level of attainment. That is, such measures are taken as the time or number of errors required by subjects to sort instances correctly into categories on the basis of attributes which the experimenter has designated as relevant. In fact, if measures were taken of the subjects' ability to give a definition of the concept in terms of its relevant attributes, they might well show that some subjects could do this while others could not, even though both types of subjects performed about equally on the sorting task. In terms of the CLD model, the former type of subject has attained the concept at a higher level than the latter subjects. Studies by Henley (cited in Deese, 1967) and by LeFurgy, Woloshin, and Sandler (1969), which have measured both classification behavior and verbal definitions, have shown that subjects, especially young children, can learn to identify examples and nonexamples of a concept without being able to indicate the defining attributes of the concept. In view of this evidence, we have designated a distinct level of concept attainment, although, for many subjects, learning many concepts, this level of concept attainment merges quickly into the formal level.

PS 007169

Formal Level

The learner has attained a concept at the formal level when he can give the name of the concept and define the term; identify and name the defining attributes of the concept; and evaluate examples and nonexamples of the concept in terms of the defining attributes. The distinctive aspect of this level of concept mastery is the learner's ability to identify and name the defining attributes of the class.

Prior to final attainment at the formal level, the learner may either infer the defining attributes from concept instances or from being given a definition of the concept that includes the defining attributes. Consider

first the case where he must infer the defining attributes. The cognitive operations entailed in this inference are outlined in Figure 4. Again, attainment of prior levels of mastery are postulated as necessary precursors to attainment of the formal level (at least for concepts with perceptible instances).

A first prerequisite to inferring the concept is discriminating and labeling the attributes of instances. This provides a basis for hypothesizing the attributes which might be relevant to the concept and makes it possible to verbalize the defining attributes after they have been inferred. In many cases, the attributes of instances of a to-be-learned concept have already been discriminated and labeled in other contexts. Therefore, the learner need only analyze instances in terms of attributes in order to begin the process of inferring which attributes are relevant and which irrelevant to the concept.

The learner may infer the concept in one of two ways. Which method he uses depends on the instructions he has been given, his ability to carry out certain operations, and the kind of concept instances he is shown. One way of inferring the concept is to test hypotheses about which attributes are relevant to the concept. In this approach, the learner forms an hypothesis or guess concerning an attribute or combination of attributes he thinks is relevant to the concept, he remembers the hypothesis, and he evaluates the hypothesis against new information.

So much research has been conducted concerning the nature of the hypothesis-testing process that it cannot be adequately summarized here. Let me just list some of the conclusions which appear to be substantiated by this literature:

1. Subjects formulate hypotheses concerning the nature of the concept, and these hypotheses, in turn, guide their classification of instances (e.g., Erickson, 1968; Levine, 1966; Rourke and Trabasso, 1968).
2. Complex, real-life concepts are usually defined by two or more attributes which are related by a particular rule structure. In learning the concept, the subject must learn not only which are the relevant attributes but also how they are combined to define the concept (e.g., Haygood and Bourne, 1965).
3. Hypothesizing behavior of the subject is influenced by his familiarity with the rule structure of the concept. Instructions which specify the rule structure facilitate concept learning (e.g., Haygood and Bourne, 1965).
4. Subjects change their hypotheses when they are told that their classification of an instance is wrong. A subject may also change his conception of what hypotheses may still be tenable when he is told that a classification is correct (e.g., Dodd and Bourne, 1969; Levine, 1966; Nahinsky and Slaymaker, 1969).
5. During the course of concept learning, new hypotheses are formed which are compatible with previously gained information. This implies that subjects have some memory for past hypotheses as well as memory for stimulus information gained from prior instances (e.g., Levine, 1962; Stein and Erickson, 1968; Williams, 1971).
6. Memory for hypotheses may serve two functions. First, the subject maintains his current hypothesis in storage and responds on the basis of that hypothesis until it leads to an incorrect classification. Second, the subject's memory for prior hypotheses guides

his selection of a new hypothesis when his current hypothesis is disconfirmed. Memory for prior stimulus information is utilized when a subject must change his hypothesis. Subjects may scan stored information about previously presented stimuli and formulate a new hypothesis which is logically consistent with this information. Once a new hypothesis is formulated it is evaluated against new information (e.g., Hunt, Marin, and Stone, 1966; Williams, 1971).

7. In evaluating hypotheses, subjects, under ideal conditions, appear to check attribute values in the hypothesis against values contained in examples and nonexamples of the concept (Hunt, Marin, and Stone, 1966; Trabasso, Rollins, and Shaughnessy, 1971; Williams, 1971).
8. Subjects' performance in concept learning tasks is facilitated by instructions in the use of logical decision rules for evaluating hypotheses (e.g., Archer, Bourne, and Brown, 1955; Klausmeier and Meinke, 1968).

The hypothesis-testing approach to inferring concepts at the formal level can be contrasted with the commonality approach, which we speculate may be utilized by young children because it entails less demand upon the learner for logical reasoning than does generating and evaluating hypotheses. The basic operation in this approach as described by Tagatz and his associates (Tagatz, 1967; Tagatz, Walsh, and Layman, 1969) is cognizing the attributes common to positive instances. Instead of actively testing the relevance of attributes in his hypothesis by utilizing information from examples and nonexamples of the concept, the learner who employs the commonality approach merely tries to identify those elements common to examples.

My discussion has centered on the cognitive operations involved in inferring a particular concept including its defining attributes. We should briefly consider what takes place when the learner is given the concept definition--as is frequently the case in school learning. In this case, we cannot be certain that the learner knows the concept merely because he can repeat the concept definition. He may be able to do this purely on the basis of rote learning. To be certain he understands the concept we must also see whether he can correctly identify examples and nonexamples. The basic process entailed in this identification is evaluating instances to determine whether they have the defining attributes given in the definition. This requires that the learner discriminate the attributes of instances and have their proper labels.

This concludes my discussion of the cognitive operations specified by the CLD model. As noted earlier, the ability to carry out the operations at each level together with the attainment of the concept at the preceding level constitutes the internal conditions of concept learning. The effects on concept learning of variables external to the learner can be understood in terms of their relationship to these internal conditions. Research on external conditions of concept learning will be discussed in a later paper.

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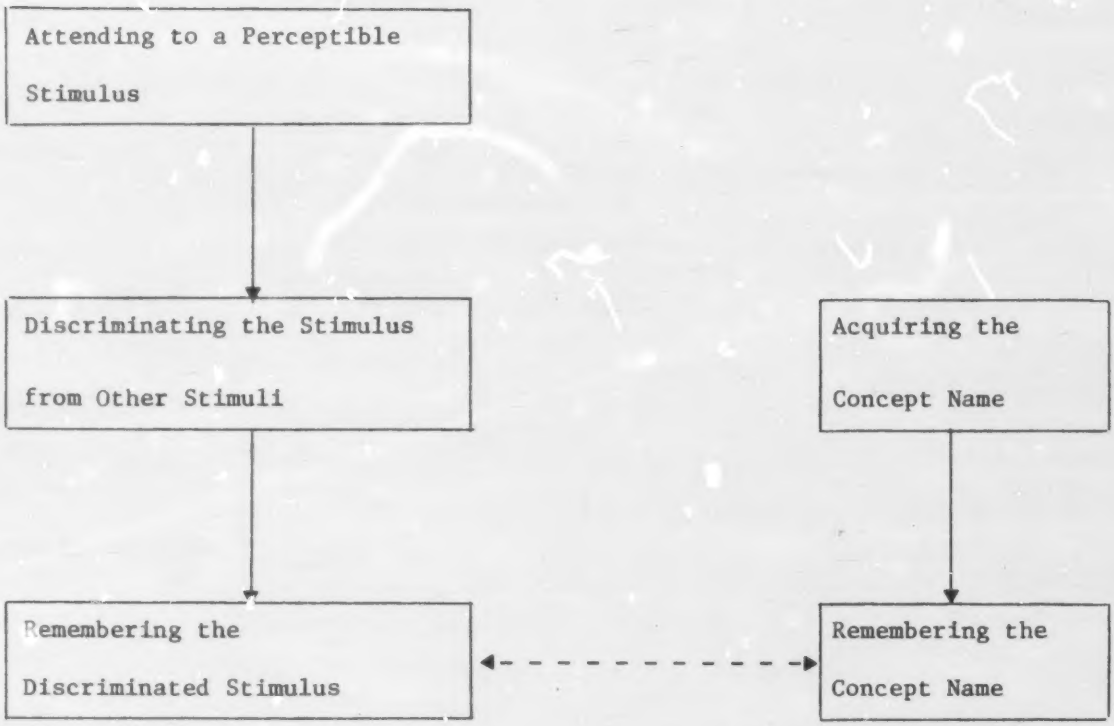
Attending to a Perceptible Stimulus
Discriminating the Stimulus from Other Stimuli
Acquiring the Concept Name
Remembering the Discriminated Stimulus
Remembering the Concept Name

Figure 1. Cognitive operations in attaining the concrete level.

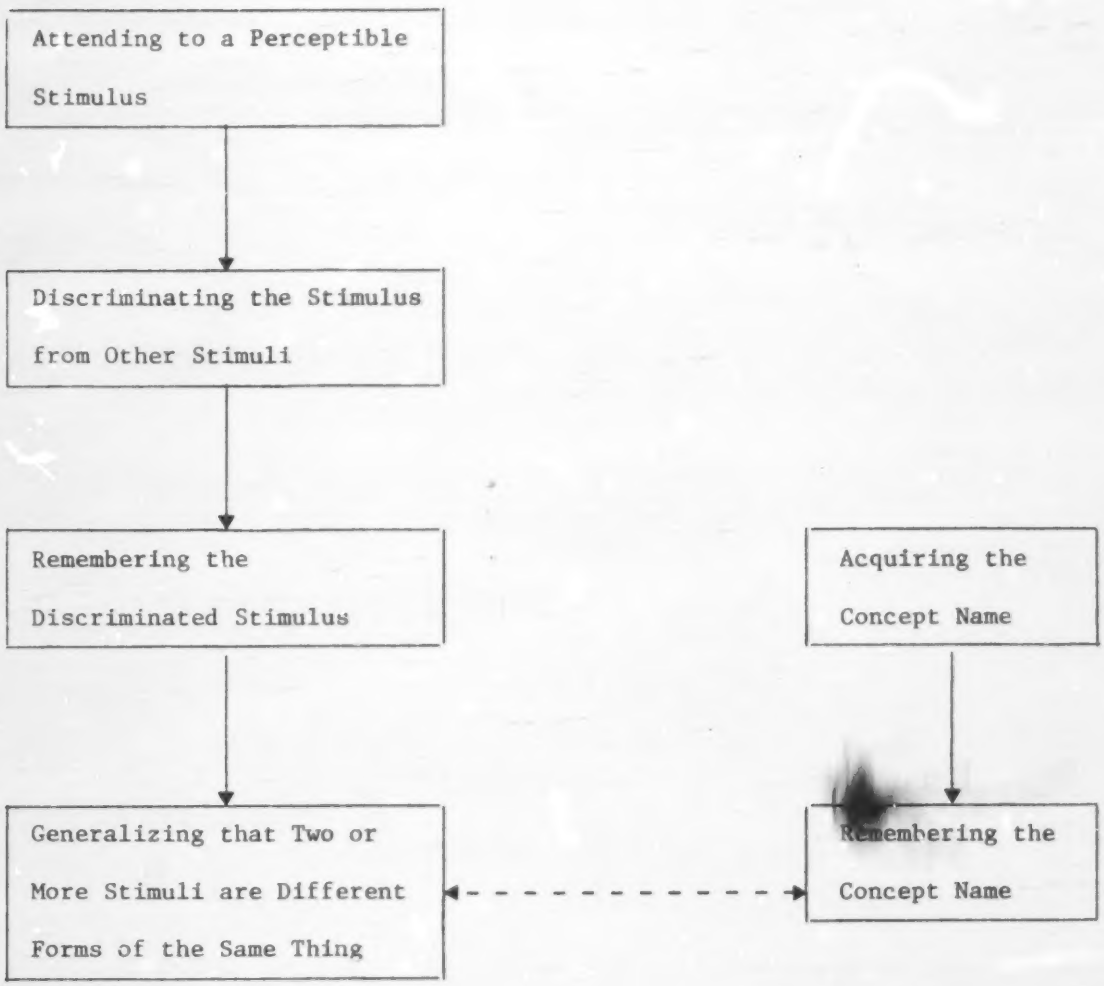
Attending to a Perceptible Stimulus
Discriminating the Stimulus from Other Stimuli
Remembering the Discriminated Stimulus
Acquiring the Concept Name
Generalizing that Two or More Stimuli are Different Forms of the Same Thing
Remembering the Concept Name

Figure 2. Cognitive operations in attaining the identity level.

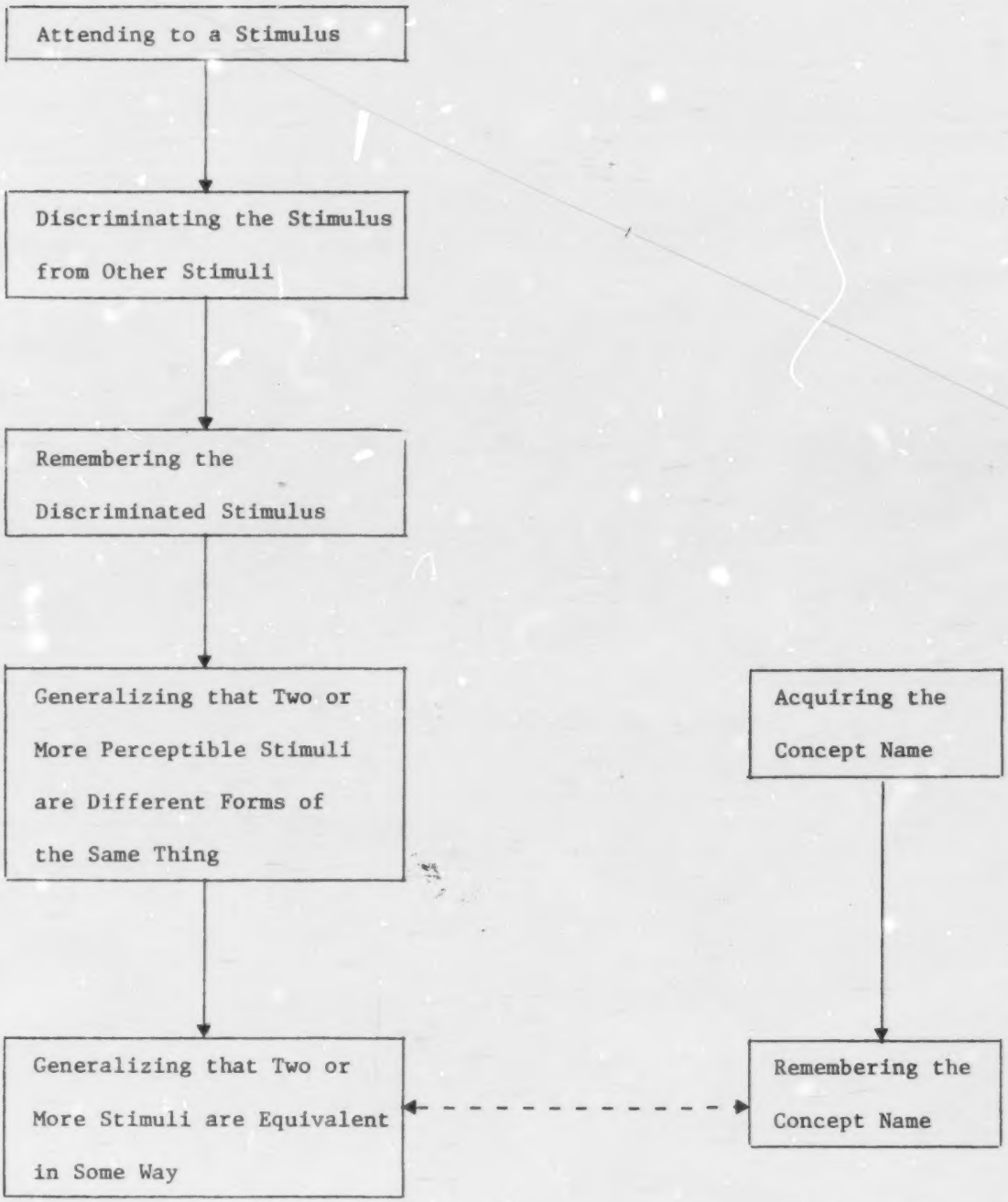
Attending to a Stimulus
Discriminating the Stimulus from Other Stimuli
Remembering the Discriminated Stimulus
Generalizing that Two or More Perceptible Stimuli are Different Forms of the Same Thing
Acquiring the Concept Name
Generalizing that Two or More Stimuli are Equivalent in Some Way
Remembering the Concept Name

Figure 3. Cognitive operations in attaining the classificatory level.

Attending to a Stimulus
Discriminating the Stimulus from Other Stimuli
Remembering the Discriminated Stimulus
Generalizing that Two or More Perceptible Stimuli are Different Forms of the Same Thing
Generalizing that Two or More Stimuli are Equivalent in Some Way
Acquiring the Attribute Names
Discriminating Attributes of the Stimulus
Remembering the Attribute Names
Hypothesizing Relevant Attributes and/or Rules
Remembering Hypotheses
Cognizing Common Attributes of Positive Instances
Evaluating Hypotheses Using Positive and Negative Instances
Acquiring the Concept Name
Inferring the Concept
Remembering the Concept Name

Figure 4. Cognitive operations in attaining the formal level.